ttH at the LHC and prospect for the future

Peter Onyisi (UT Austin), Robert Kehoe (SMU)

Snowmass Energy Frontier Mtg.
BNL 04/03/13

Some Thoughts

- m_t = 173.18 ± 0.95 GeV (Tevatron avg.)
  - 0.5% measurement!
  - Indirect Yukawa coupling (=mt/(sqrt(2)^vev)
    - 0.996 ± 0.005
      - Why? (or why are others << ?)

- Need to measure Y_t directly
  - A fundamental SM parameter

- How well can we do?
  - 300 fb-1
  - 3000 fb-1

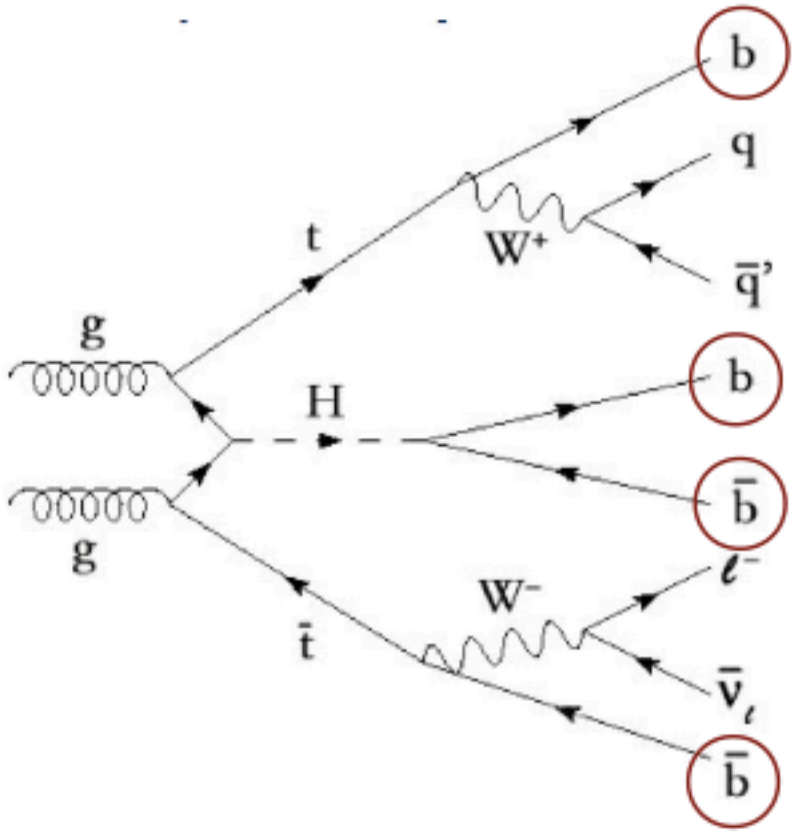
“Channels”

- Have grouped according to Higgs decay modes for convenience
  - tends to be how studied, but overlaps of acceptance should be identified
  - BGs in many cases set by ttbar+X
- Had a 1st mtg. March 25th
  - Interest in several aspects on ATLAS side
  - Want to have input from CMS too (recent announcement from A. Gritsan)
  - Combinations of measurements across channels and experiments
    - Get total sensitivity
    - Are systematic limitations a problem for HL-LHC?
  - Use a ‘May workshop’ to facilitate discussion as a step to Seattle

tt H → bb

ATLAS-CONF-2012-135

Dataset: 4.7 fb^{-1} for $\sqrt{s}$ = 7 TeV



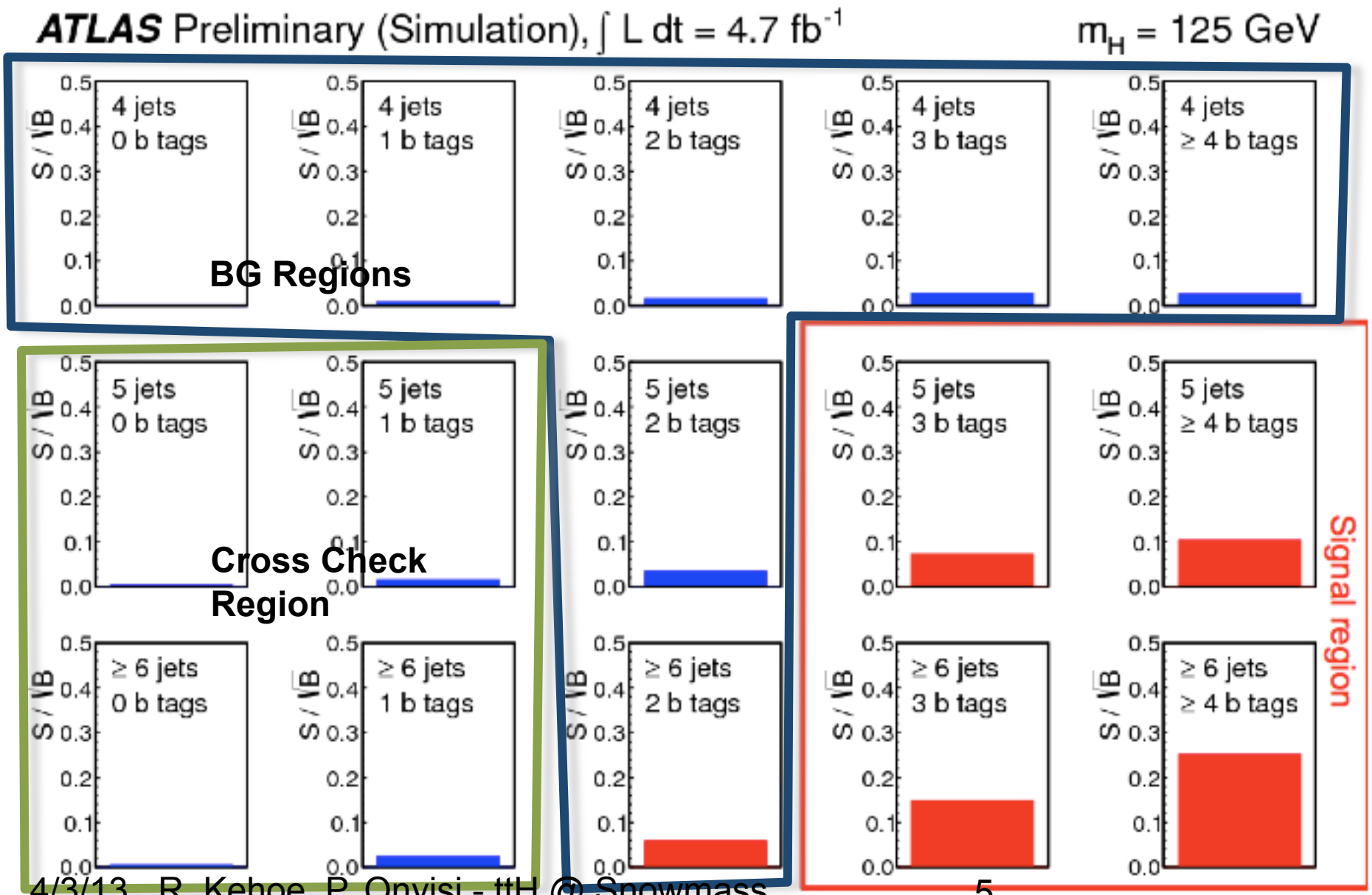
Signature of lepton+jets channel:

- High jet multiplicity,
  4 b-jets from top and Higgs
  ≥ 4 jets with p_T > 25 GeV
- High p_T isolated e or μ (single lepton trigger)
  exactly 1 e (p_T > 25 GeV) or
  μ (p_T > 20 GeV)
- High missing transverse energy
  e: E_T^{miss} > 30 GeV, m_T > 30 GeV
  μ: E_T^{miss} > 20 GeV,
  $E_T^{miss} + m_T$ > 30 GeV

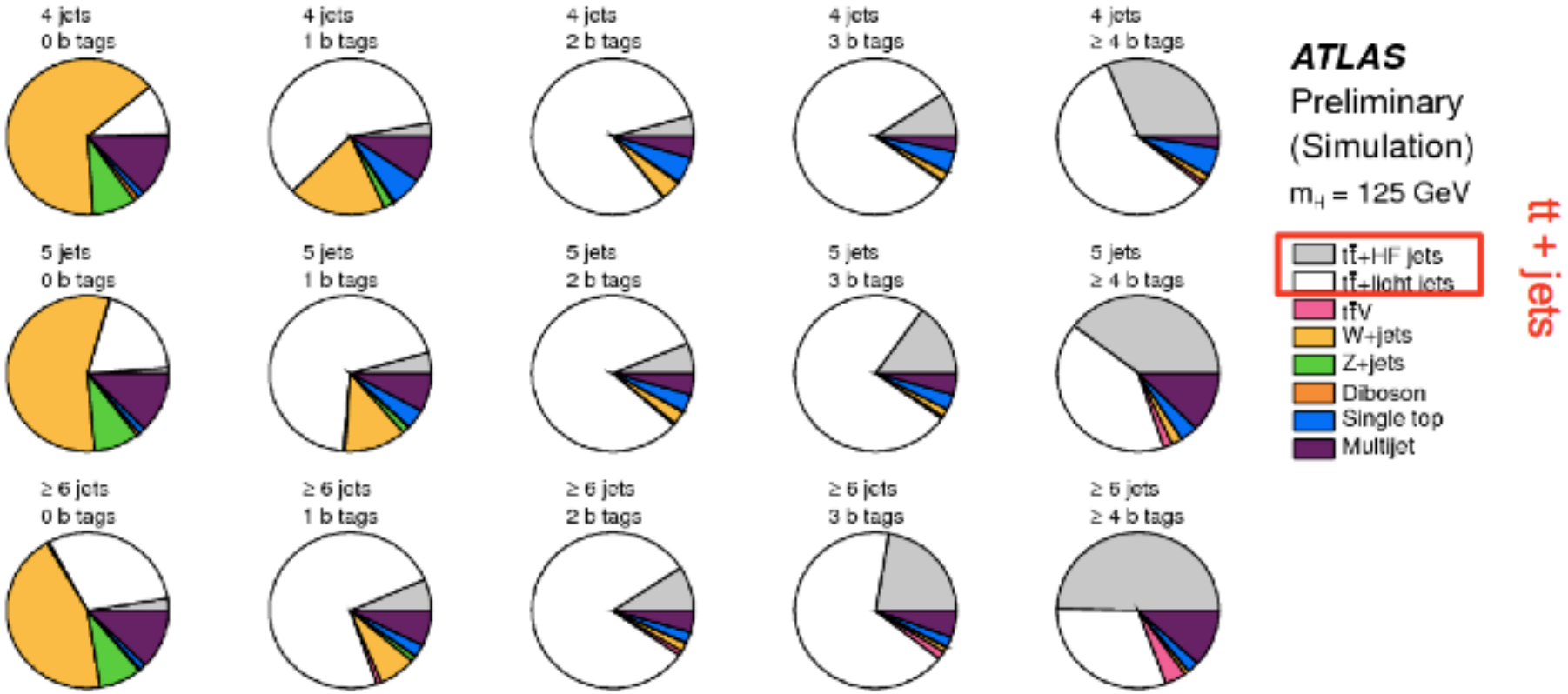
Perform kinematic reconstruction of ttbar

Define signal and background enriched categories based on jet and b-tag multiplicities
(B-Tagging algorithm with ≈70% b-tag efficiency)

Event Topologies



Background Composition



- W+jets: shape from simulation, normalisation from data (exploit charge asymmetry)
- QCD multijet: Data driven estimate for shape and normalisation
- ttbar+X, Z+jets, single top: shape from simulation, normalisation to theoretical x-section

Event Yields

	≥ 6 jets, 3 b tags	≥ 6 jets, ≥ 4 b tags
$t\bar{t}H(125)$	4.0 ± 0.2	2.2 ± 0.1
$t\bar{t}$+ jets	560 ± 20	54 ± 5
W+jets	8 ± 3	0.7 ± 0.3
Z+jets	0.4 ± 0.2	0.01 ± 0.01
Single top	15 ± 1	1.5 ± 0.2
Diboson	0.09 ± 0.03	0.01 ± 0.01
$t\bar{t}V$	13 ± 4	2.7 ± 0.7
Multijet	34 ± 10	4 ± 3
Total bkg.	634 ± 19	62 ± 5
Data	676	65
S/B	0.006	0.035
S/√B	0.16	0.28

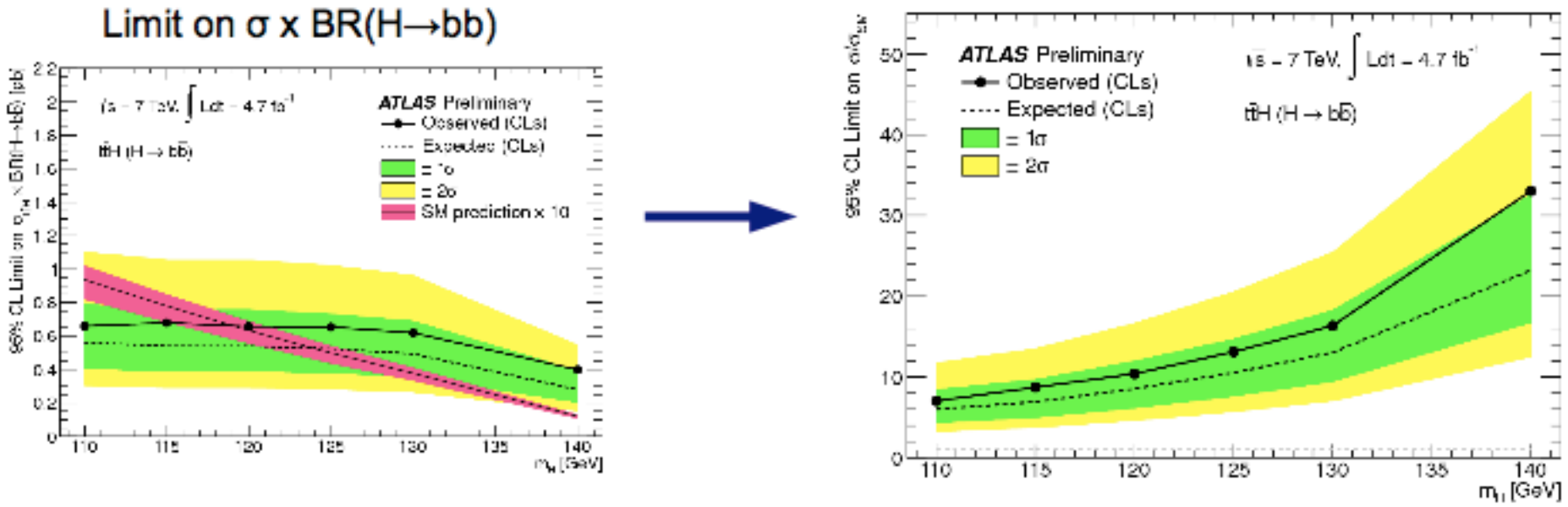
4.7 fb^{-1}

7 TeV

Major syst.

- Jet energy scale
- B and c jet efficiency
- Multijet normalization

ttH Limits



m_H (GeV)	observed	-2 s.d.	-1 s.d.	median	+1 s.d.	+2 s.d.	stat only
110	7.0	3.2	4.3	6.0	8.5	11.8	3.5
115	8.7	3.7	5.0	6.9	9.7	13.6	4.0
120	10.4	4.6	6.2	8.5	12.0	16.7	4.9
125	13.1	5.7	7.6	10.5	14.7	20.6	6.1
130	16.4	7.0	9.4	13.0	18.3	25.5	7.8
140	33.0	12.5	16.7	23.2	32.7	45.5	14.2

For m_H = 125 GeV:

- Observed limit 13.1 x SM
  Expected limit 10.5 x SM

  (statistics only: 6.1 x SM)

- tt + heavy flavour fraction biggest systematic

Published feasibility study: $\tau\tau$

Boddy, Farrington, Hays: Phys.Rev. D86 (2012) 073009

- Associated production modes
  - WH, ZH, ttH with Higgs to tau tau
  - Combine with published studies of Higgs to bb
- Evaluated couplings uncertainties for 100fb^{-1} of 14TeV data
  - gHbb/gH$\tau\tau$, gHtt/gHWW, gHWW/gHZZ
- Parametric detector simulation: Delphes
  - Input ATLAS tau reconstruction efficiencies
- MC: Sherpa for all processes except W+6 jets
- Prior studies
  - E. Gross, L. Zivkovic, Eur. Phys. J. C59, 731 (2009)
  - A. Belyaev, L. Reina, J. High Energy Phys. 0208, 041 (2002)

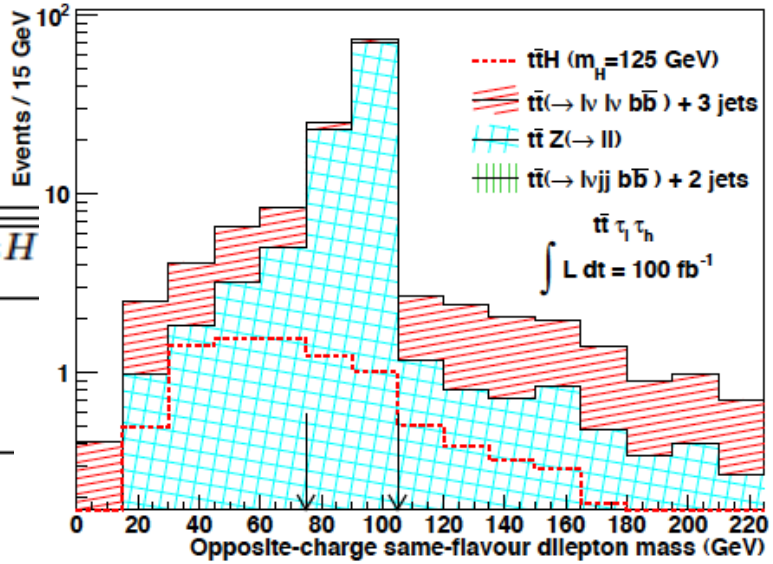
ttH, H to tau tau

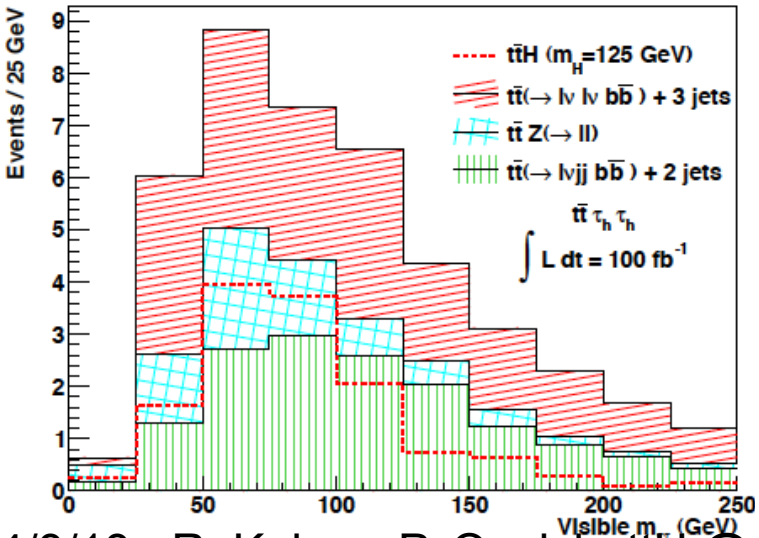
- Our study excludes the fully hadronic tt mode
- We consider $t\bar{t} \to l_W \nu q\bar{q} b\bar{b}$ and either $H \to \tau_h\tau_h$ or $H \to \tau_l\tau_h$, with l_W defined by $p_T^{lW} > p_T^{\tau_l}$
- Dominant backgrounds
  - ttZ (irreducible, but suppress with mass cut $l_W\tau_l$)
  - tt+jets (reducible, driven by tau ID)
- Require pt(l_W)>25, pt(τ_h), pt(τ_l) >15 GeV
  - Trigger is an issue

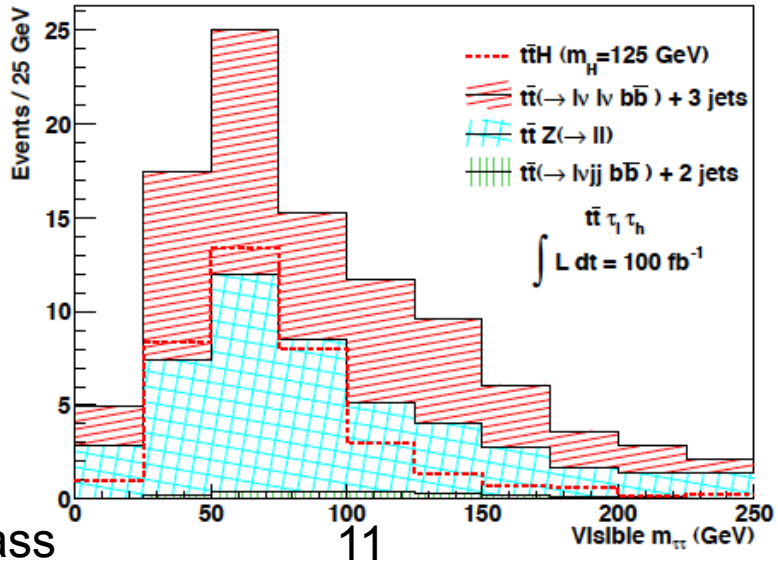
ttH, H to tau tau Results

- Sensitivity at 100 fb^{-1}

m_H (GeV)	Channel	N_s^{ttH}	$N_s^{ttH}/\sqrt{N_b^{ttH}}$
125	$t\bar{t}+\tau_h\tau_l$	37	3.7
	$t\bar{t}+\tau_h\tau_h$	14	2.1







Prospects: $\tau\tau$

- Studies show 4 sigma sensitivity with 100fb^{-1} (one experiment)
- higher luminosity scenarios
  - Systematics probably dominate beyond 300fb^{-1}
- But: limiting factors are
  - tau ID efficiency
  - trigger thresholds
- These are challenging both because of difficulty extrapolating values and may hit a wall with experimental capability
- An open question whether benefit from HL-LHC

H→WW

V. Garcia, Y. Ilchenko, R. Kehoe, P. Onyisi

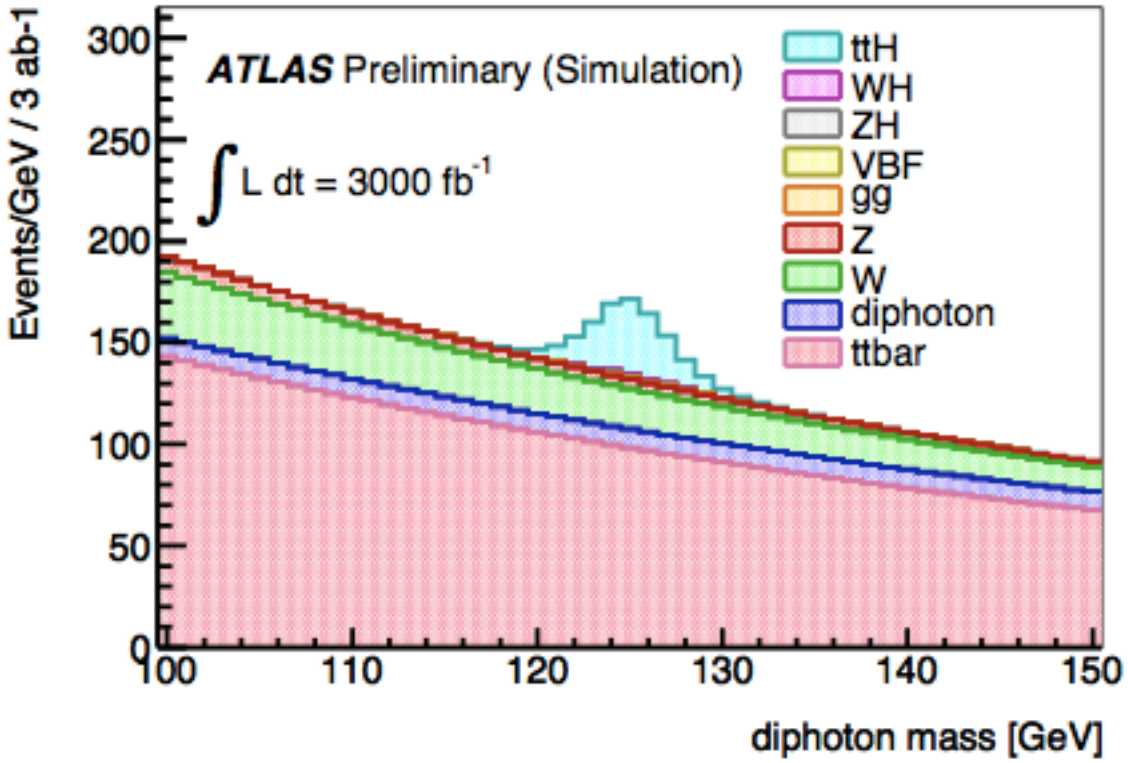
- H->WW has a lot of BR at 125 GeV
- For ttH: 4W + bb
  - Consider trilepton, same sign dilepton final states
    - Includes semileptonic H decays
    - Physics BGs are production of tt+V(V)
      - X = W, Z/γ*, WW
    - Instrumental BG: fake rate critical
- Early ATLAS studies (2008, 2002)
  - S:B ~1:1 with minimal cuts
  - Except for tt+jets: S:B highly dependent on fake rate
- Other studies on arXiv find similar results
- Study optimization of selections (& MVA); plan white paper

WW: Simulation

- LO look (generation at UT Austin)
  - MadGraph
  - Generate tt+γ* (<10 GeV mass) using Sherpa
  - Signal thru Pythia6 to Delphes (2)
    - Delphes 3 working today
  - So far, with no cuts, S/B > 1 for all but tt+jets
    - ttWW BG almost negligible
- NLO from aMC@NLO
  - successful validation of cross section calculations
- Use Delphes 'Snowmass' detector configuration

ttH, H→γγ long term

- Clean channel studied with 3 ab^{-1} for European Strategy workshop using truth smearing/truth quantities. Very simple cuts of == 1 lepton + diphotons + >= 4 jets. No b-tagging needed!
  - s/sqrt(B) = 5.9
  - Could easily be more sophisticated



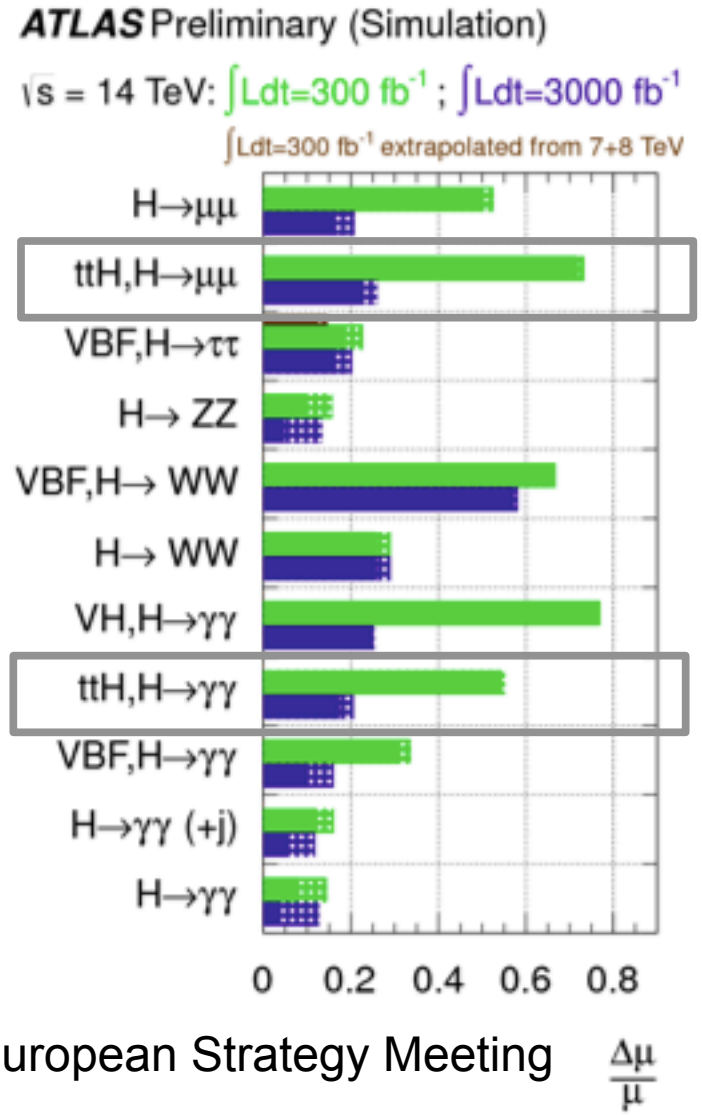
- Would be great to repeat for Snowmass. Not clear yet the best place to do it, with what detector or collider or how best to repeat ATLAS studies

Putting it all together

ttH sensitivity @ 14 TeV (I)

E. Feng

- Expected precision with 300 & 3000 fb^{-1} @ 14 TeV
  - ATL-PHYS-PUB-2012-004
- Signal strengths, μ_i, and partial widths, Γ_i (proportional to squared coupling constants)
  - Hashed areas indicate theoretical uncertainties
  - No assumptions on new physics i.e. total Higgs width
- ttH signal strengths measurable to 55-75% (20-25%) precision with 300 (3000) fb^{-1}, depending on decay channel
- Γ_t / Γ_g constrains possible new physics with massive colored particles in ggF loop at 50% (22%) level with 300 (3000) fb^{-1}



Plot from European Strategy Meeting

ttH sensitivity @ 14 TeV (II)

- Expected precision with 300 & 3000 fb^{-1} @ 14 TeV
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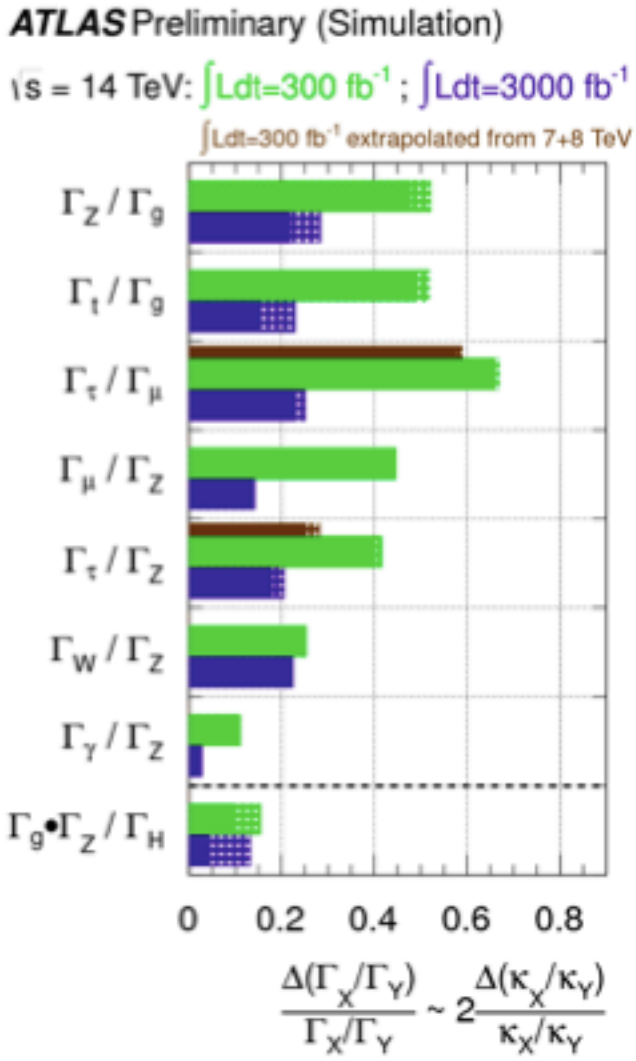

Trigger

- Studies starting for ATLAS trigger upgrade
  - D. Strom
  - TDR timescale similar to Snowmass
  - What are the critical path items for ttH in trigger?
    - Channel-by-channel needs
- Similar questions on CMS side?

MC samples

- Bottleneck and manpower limitation with generating all channels at Austin
  - Using university HPC resources
- Madgraph LHE files (14 TeV):
  - Signal & WW BGs can be done at UT
  - bb, γγ, ττ BG
    - can generate a request of these samples
- Pythia showering, Delphes simulation:
  - Pythia, no-pileup Delphes straightforward with ATLAS grid resources
  - Need to understand how to proceed with pileup.
  - Eagerly want to know computing plan

ttH Workshop in May

https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=240704

- Goals
  - Bring groups of similar interest together, share knowledge and experience
  - Inform about progress, identify questions, bottlenecks to further progress
  - First day of workshop dedicated to Snowmass studies with Snowmass detector
- May 3-4 at University of Texas, Austin
  - If you can't be present but will connect, you can indicate it on the registration
  - **Please Register!!!**

Tentative Agenda

- May 3 (Friday) is Snowmass session
- Overview session
  - MC status, points from April meeting, phenomenology
- Block sessions: bb, ττ, γγ, WW, rare (ZZ, μμ)
- Summary
  - Is there anything further to convey/ask for Snowmass?
    - (eg. MC samples)
    - To prepare for June meeting
- May 4 session discusses points in ATLAS context